Project: eems080
Pillar(s) Urban Science

U.S. DEPARTMENT OF ENERGY
SMARTMOBILITY
Systems and Modeling for Accelerated Research in Transportation

Typology of Cities for Systems and Modeling for Accelerated Research in Transportation (SMART) Mobility Consortium

Paty Romero-Lankao
National Renewable Energy Laboratory
2019 Vehicle Technologies Office Annual Merit Review
June 11, 2019

Argonne National Laboratory | INL Idaho National Laboratory | Berkeley Lab | Oak Ridge National Laboratory | NREL National Renewable Energy Laboratory

OVERVIEW

Timeline

- Project start date: 12/01/19
- Project end date: 09/30/19
- Percent complete 30%

Budget

- Total project funding: $300
  - DOE share: $300
  - Contractor share: $0
- Funding for FY 2017 **$0**
- Funding for FY 2018 **$0**

Barriers

- Barriers addressed
  - Cross city applicability of SMART mobility research findings
  - (https://energy.gov/eere/vehicles/us-drive-partnership-planroadmaps-and-accomplishments)

Partners

- LBLN, MEP, Cities LEAP, MIT, School of Mines, Oak Ridge, PenState
- PI: Paty Romero-Lankao

OVERVIEW

1. **Enhance the value of SMART Mobility efforts by**

   - making relevant outcomes transferable among cities with similar characteristics

2. **Create a multi-dimensional typology of adoption/impacts**

   - of emerging technologies in urban areas
   - geographic information system (GIS)-based for reuse and sharing

RELEVANCE

Project objectives

1. **Enhance the value of SMART Mobility efforts by making**
   - Outcomes transferable among cities with similar characteristics
2. **Create a multidimensional typology of adoption/impacts**
   - GIS-based for reuse and sharing
   - Social, economic, technological, environmental and governance (SETEG) indicators relate with technology adoptions
   - Examine variations across settlements and status groups
3. **Compare clustering methods and variables with similar geo-typology**

RELEVANCE

- **Outcomes/Impact from AOP**
  - Clustering of cities and settlements by common characteristics for estimating national impact of automated, connected, efficient and shared transportation scenarios (NREL)
  - Accessible data, analytics, and methods for SMART researchers and Cities partners on urban characteristics across many dimensions (NREL)
  - Grouping of similar cities and settlements into a small (10 to 15) number of clusters (NREL)
  - White paper of possible approaches and data to be used to create geotypes for FHWA project (LBNL)

AOP: Annual Operating Plan
FHWA: Federal Highway Administration
LBNL: Lawrence Berkeley National Laboratory
NREL: National Renewable Energy Laboratory

MILESTONES

- First quarter (Q1) – Urban data availability spreadsheet – initial and ~~&~~ updated on an ongoing basis, indicating both available data and gaps
- Q3 – Analytic tools of multi-layer urban data layers for SMART clustering analysis, integrated into Cities Leading through Energy Analysis and Planning (Cities-LEAP)
- Q4 –White paper and journal article summarizing the methods and findings of the clustering analysis

APPROACH

1. Analyze dimensions of urban areas
   - e.g., socioeconomic, technological

2. Build on/coordinate with existing efforts (Cities-LEAP, Mobility Energy Productivity [MEP], FHWA geotypology)

3. Conduct systemic literature review

4. Run factor analysis, cluster analysis, and correlations

5. Run Ordinary Least Squares (OLS) to examine links between population clusters/settlement type and adoption/impacts

6. Run sensitivity of geotypology results to alternative approaches and variables

Data
SMART -> Cities-LEAP -> Robust Multi-Layer Typology Resource

Indicator	Type	Domain	Source	Spatial level	Year
Total/group age	Independent	Social	American FactFinder	Census block	2016 5-Year
Total/group age	Independent	Social	American FactFinder	Census block	2016 5-Year
Gender	Independent	Social	American FactFinder	Census block	2016 5-Year
Education	Independent	Social	American FactFinder	Census block	2016 5-Year
Race	Independent	Social	American FactFinder	Census block	2016 5-Year
Median Income	Independent	Economic	American FactFinder	Census block	2016 5-Year
House tenure	Independent	Economic	American FactFinder	Census block	2016 5-Year
Vehicles per household	Independent	Economic	American FactFinder	Census block	2016 5-Year
Affordability: housing + transportat	Independent	Economic	CNT H&TA Index;	Census block	2015
Population density	Independent	Techno-infras	CNT H&TA Index;	Census block	2015
Residential density	Independent	Techno-infras	CNT H&TA Index;	Census block	2015
Employment access index (job den	Independent	Techno-infras	CNT H&TA Index;	Census block	2015
Intersection density	Independent	Techno-infras	CNT H&TA Index;	Census block	2015
Heating/cooling degree days	Independent	Environment	ftp://ftp.cpc.ncep.noaa.gov/htdocs/degree_days/		2016
Carbon/energy intensity	Independent	Environment	https://www.eia.gov/environment/	Census block	2016
Air toxics respiratory hazard index	Independent	Environment	EPA EJS	Census block	2011
Hazard index (risk of) respiratory effec	Independent	Environment	EPA EJS	Census block	2011
Traffic proximity and volume:	Independent	Governance	EPA EJS	Census block	2014
Transportation mode choice	Independent	Governance	American FactFinder	Census block	2016 5-Year
Compactness	Independent	Governance	CNT H&TA index	Census block	2016 5-Year
EV adoption	Dependent		IHS Markit vehicle registration data	ZIP code	2017
Annual GHG per Household co2_pe	Dependent		CNT H&TA index	Census block	2015
Annual GHG per Acre autos_per_hh	Dependent		CNT H&TA index	Census block	2015
Diesel particulate matter level in air	Dependent		EPA EJS	Census block	2013
$PM_{2.5}$ level in air	Dependent		EPA EJS	Census block	2011

EV: electric vehicle
GHG: greenhouse gas

APPROACH

Typology: Dataset
(20 indicators/9,405 census blocks)

blkgrp	total_pop	gender_fem	education	race_whi	income_hh	not_sov_com	tenure_own	vehicl_hh	hta_index
6.0014E+10	3018	0.5036448	0.65639496	0.72664016	177417	0.42516129	86	2.02	76
6.0014E+10	1105	0.46877828	0.64434389	0.80542986	166313	0.46241135	69	1.69	55
6.0014E+10	855	0.57192982	0.6619883	0.8	132400	0.60810811	58	1.59	54
6.0014E+10	1466	0.50886767	0.60163711	0.6255116	161964	0.39609644	61	1.66	60
6.0014E+10	1265	0.5083004	0.64110672	0.73438735	79375	0.60664112	36	1.42	43
6.0014E+10	985	0.56548223	0.32893401	0.46903553	29736	0.54095563	18	1.31	31

pop_dens	hh_dens	intersect_dens	compactness	empl_access	ghg_hh_est	diesel_pm	pm_25	cancer_haz	respi_haz
437.750387	0.75	70	4.1	44078	8.09	0.7929689	9.66098055	31.7208835	1.79037497
3835.85991	6.32	385	7.2	68635	6.57	2.37348276	9.66278932	44.7120749	3.17394049
2864.41757	5.17	381	8.1	71540	6.1	2.37348276	9.66278932	44.7120749	3.17394049
5517.60477	7.42	380	7.5	70955	7.13	2.32813856	9.66012959	45.595051	3.22848943
4696.54386	10.54	558	9.1	87745	4.88	2.32813856	9.66012959	45.595051	3.22848943
3368.71913	7.61	674	9.6	84942		2.32813856	9.66012959	45.595051	3.22848943

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Correlation matrix shows links between

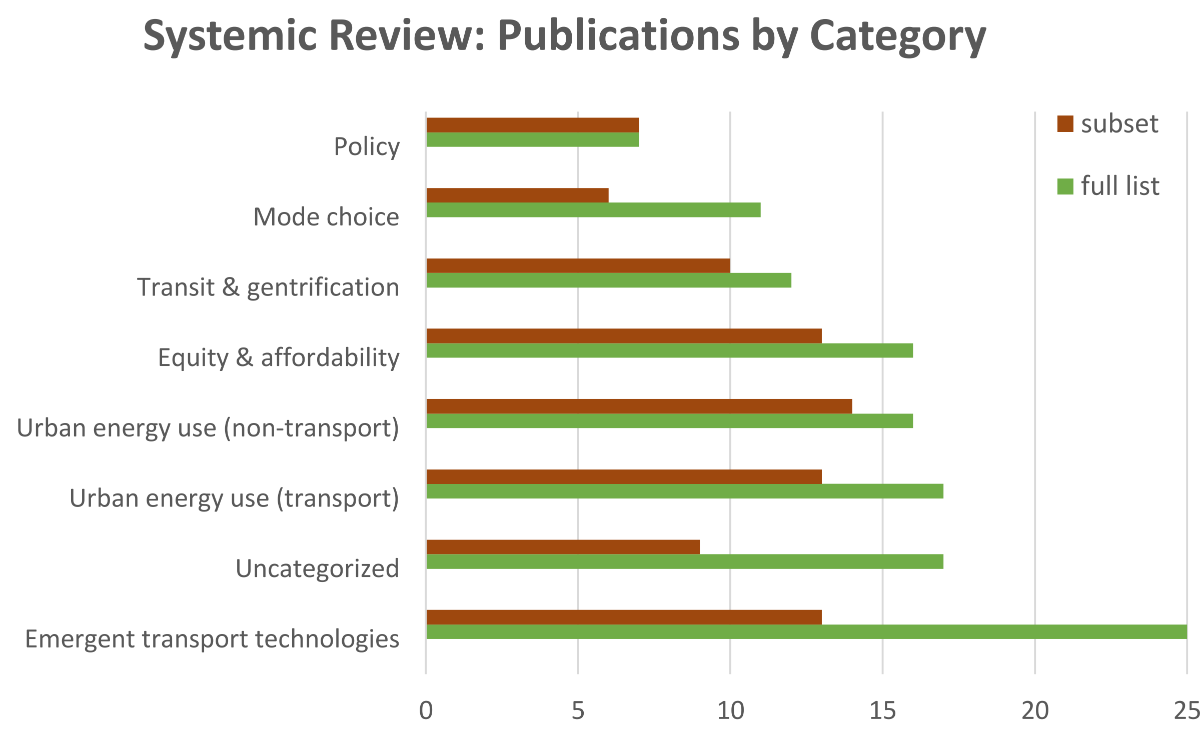
- Socioeconomic status (e.g., income) and urban form (e.g., compactness) indicators
- Urban form (e.g., population density) and impacts (e.g., emissions) indicators

	total_pop	gender_fem	education	race_whi	income_hh	not_sov_com	tenure_own	vehicl_hh	hta_index	pop_dens	hh_dens	intersect_dens	compactness	empl_access	ghg_hh_est	diesel_pm	pm_25	cancer_haz	respi_haz
total_pop		-0.04605	0.005088	-0.05208	0.125458	-0.049227	0.005607	0.090111	0.105123	0.040139	0.006462	-0.145727	-0.045533	-0.02557	0.153812	-0.038436	0.019324	-0.002167	-0.008102
gender_fem	-0.04605		0.03381	-0.08119	-0.052851	0.025521	-0.029461	-0.101573	-0.062806	0.059294	0.067219	0.068474	0.093391	0.028765	-0.116065	0.066789	0.048171	0.057687	0.050576
education	0.005088	0.03381		0.170862	0.683677	0.117766	0.159091	-0.08945	0.346604	0.100449	0.197285	0.096631	-0.003828	0.309816	-0.130457	0.195851	-0.040563	0.140972	0.171227
race_whi	-0.052084	-0.081189	0.170862		0.193051	-0.40593	0.432763	0.431457	0.394307	-0.335788	-0.256958	-0.423329	-0.517865	-0.198322	0.46275	-0.379822	-0.23432	-0.380475	-0.382988
income_hh	0.125458	-0.052851	0.683677	0.193051		-0.05954	0.474285	0.251799	0.626837	-0.040949	-0.008787	-0.091396	-0.315522	0.121759	0.26962	0.005323	-0.040244	-0.040741	0.011912
not_sov_com	-0.049227	0.025521	0.117766	-0.40593	-0.05954		-0.469026	-0.725501	-0.369583	0.639692	0.600975	0.542039	0.529683	0.579614	-0.699454	0.658607	-0.008248	0.489811	0.484528
tenure_own	0.005607	-0.029461	0.159091	0.432763	0.474285	-0.469026		0.700778	0.667048	-0.408676	-0.374836	-0.444292	-0.824974	-0.304185	0.715158	-0.41355	-0.101833	-0.430652	-0.381265
vehicl_hh	0.090111	-0.101573	-0.08945	0.431457	0.251799	-0.725501	0.700778		0.595674	-0.713266	-0.696761	-0.680815	-0.811554	-0.659059	0.910232	-0.776796	-0.129526	-0.636789	-0.584092
hta_index	0.105123	-0.062806	0.346604	0.394307	0.626837	-0.369583	0.667048	0.595674		-0.346862	-0.319424	-0.426726	-0.646048	-0.212792	0.591818	-0.371404	-0.062308	-0.348543	-0.322297
pop_dens	0.040139	0.059294	0.100449	-0.33579	-0.040949	0.639692	-0.408676	-0.713266	-0.346862		0.930948	0.557963	0.461727	0.619754	-0.641157	0.732003	0.063918	0.526557	0.495465
hh_dens	0.006462	0.067219	0.197285	-0.25696	-0.008787	0.600975	-0.374836	-0.696761	-0.319424	0.930948		0.530329	0.428219	0.688356	-0.627122	0.730552	0.051528	0.522295	0.483405
intersect_dens	-0.145727	0.068474	0.096631	-0.42333	-0.091396	0.542039	-0.444292	-0.680815	-0.426726	0.557963	0.530329		0.689206	0.451886	-0.672012	0.612497	0.209592	0.555184	0.530962
compactness	-0.045533	0.093391	-0.003828	-0.51787	-0.315522	0.529683	-0.824974	-0.811554	-0.646048	0.461727	0.428219	0.689206		0.401357	-0.822979	0.568066	0.21119	0.584827	0.549043
empl_access	-0.02557	0.028765	0.309816	-0.19832	0.121759	0.579614	-0.304185	-0.659059	-0.212792	0.619754	0.688356	0.451886	0.401357		-0.599811	0.74297	0.09686	0.57552	0.512128
ghg_hh_est	0.153812	-0.116065	-0.130457	0.46275	0.26962	-0.699454	0.715158	0.910232	0.591818	-0.641157	-0.627122	-0.672012	-0.822979	-0.599811		-0.717773	-0.151386	-0.623342	-0.584495
diesel_pm	-0.038436	0.066789	0.195851	-0.37982	0.005323	0.658607	-0.41355	-0.776796	-0.371404	0.732003	0.730552	0.612497	0.568066	0.74297	-0.717773		0.243496	0.758219	0.744125
pm_25	0.019324	0.048171	-0.040563	-0.23432	-0.040244	-0.008248	-0.101833	-0.129526	-0.062308	0.063918	0.051528	0.209592	0.21119	0.09686	-0.151386	0.243496		0.326911	0.216271
cancer_haz	-0.002167	0.057687	0.140972	-0.38048	-0.040741	0.489811	-0.430652	-0.636789	-0.348543	0.526557	0.522295	0.555184	0.584827	0.57552	-0.623342	0.758219	0.326911		0.806066
respi_haz	-0.008102	0.050576	0.171227	-0.38299	0.011912	0.484528	-0.381265	-0.584092	-0.322297	0.495465	0.483405	0.530962	0.549043	0.512128	-0.584495	0.744125	0.216271	0.806066	

Note: This is this is not a regression yet. Red and green are negative and positive correlations, respectively. The darker shades are only stronger or weaker correlations, not statistical significance.

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Focus on multi-dimensional determinants (e.g., urban form) and impacts (e.g., on mobility and energy) of emergent technologies



RESPONSES TO PREVIOUS YEAR'S REVIEWERS' COMMENTS

- This project is new for FY 2019.

COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS

- NREL–LBNL collaborations seeking to
  - Compare applicability to freight transport of clustering methods
- Typology – MEP collaborations seeking to
  - Use MEP as dependent variable in typology regression
- Typology – Cities-LEAP collaborations seeking to
  - Consider Cities-LEAP assets and visualization tools
  - Design in the future a buildings and transportation typology

COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS

- Typology – New York collaborations to
  - Apply typology to GIS analysis of adoption of emergent transport technologies and its energy impacts

- Typology – Massachusetts Institute of Technology (MIT) collaborations seeking to
  - Compare and contrast MIT and NREL methodologies
  - Use MIT data archive as an example

- Typology – Colorado School of Mines collaborations to
  - Refine replicability of statistical methods

- Typology - PenState/Western State University collaborations (still in the making) seeking to
  - Respond to DOE VTO $59M funding opportunity.

REMAINING CHALLENGES AND BARRIERS

- We are looking for other and more accurate indicators of energy use and emissions by transport at a finer level of resolution – e.g., block census level
- We lack appropriate transportation infrastructure and mobility behavior data layers

PROPOSED FUTURE RESEARCH

If we are successful with the typology,

- **Can we identify subunits in urban areas that are consistent across different cities, independent of the difference between the cities as a whole?**

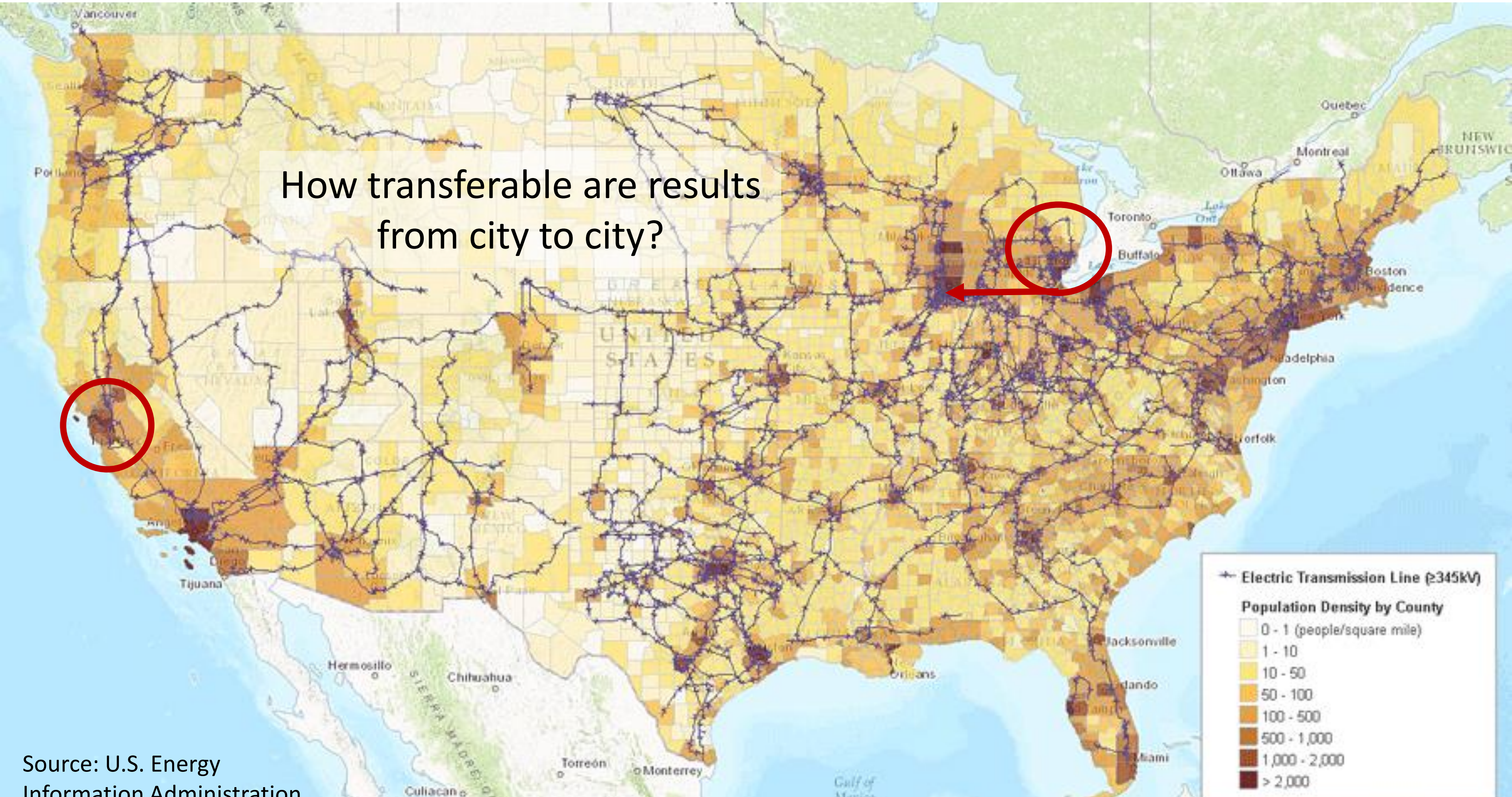
- **Can understanding ~~of~~ what happens within the subunits help inform difficulties in the adoption of efficient transportation technologies? E.g., in accommodating energy sources that are intermittent or at risk from weather extremes and cyber-attacks?**

- **Can this typology help to provide tools to project adoption scenarios across these subunits?**

Any proposed future work is subject to change based on funding levels.

SUMMARY

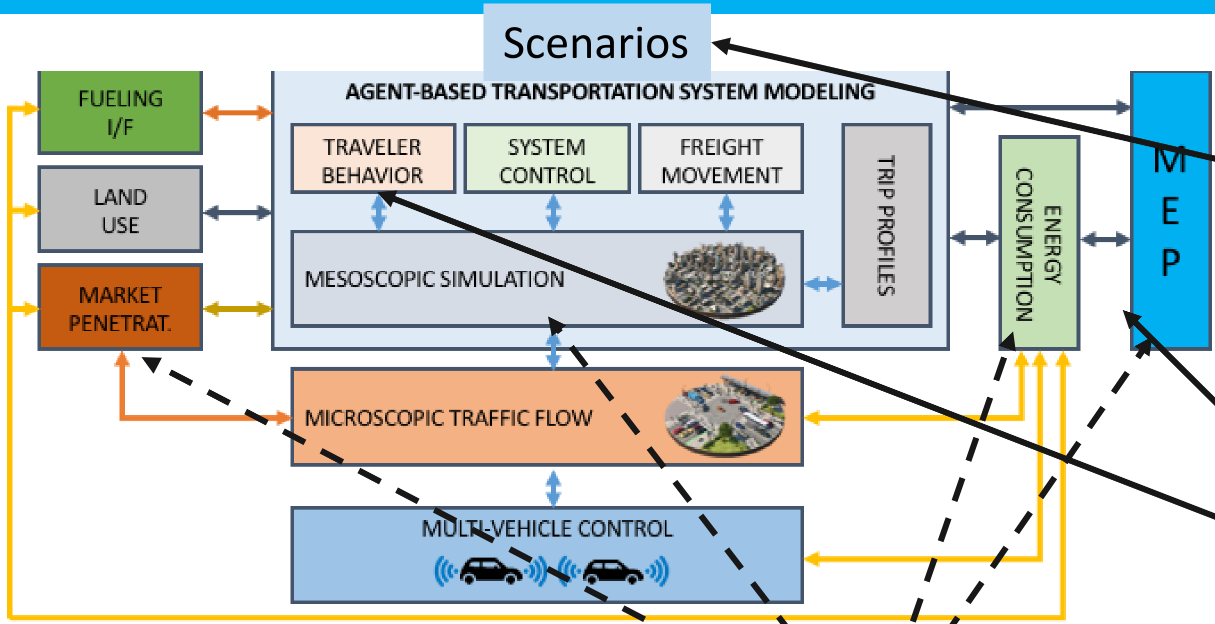
Typology to identify clusters of features in emergent transportation behavior and energy use across urban areas and socioeconomic status groups



How transferable are results from city to city?

Source: U.S. Energy Information Administration

Urban Typology Mapping to SMART End-to-End Workflow – Additional Supporting Tasks



Mortar: Review of Current SET*EG* drivers of Technology Adoption and Energy Use

Mortar: Impact of plausible trends in SET*EG* drivers in Adoption and Energy Use

Urban Typology: Data Collection and Analysis

1. SET*EG* indicators associated with transport behavior and energy use

2. Hierarchical cluster analyses for settlement and population groups

3. OLS and multivariate correlations between independent and dependent variables

4. Adoption, transport behavior, and energy use by income groups settlement clusters

5. Focused Validation to Support SMART Activities

PUBLICATIONS AND PRESENTATIONS

- Abstract was accepted to present this typology at the International Conference on Energy and Social Science in Phoenix
- The PI was invited to give a keynote on the Transformative Potential of Emergent Technologies at The “2019 Transformations Conference” in Santiago de Chile
- We intend to publish a paper to circulate internally with LBNL in a high-impact journal
- Incorporate FHWA comments into geotypology white paper and circulate externally (including with NREL) for peer review (LBNL)

CRITICAL ASSUMPTIONS AND ISSUES

- This effort presents a snapshot approach to typologies. In the future, we will combine clustering with time series and scenarios to represent the dynamic nature of our typology.

QUESTIONS?